Adaptive Informative Planning for Mobile Robots with Deployable Sensors

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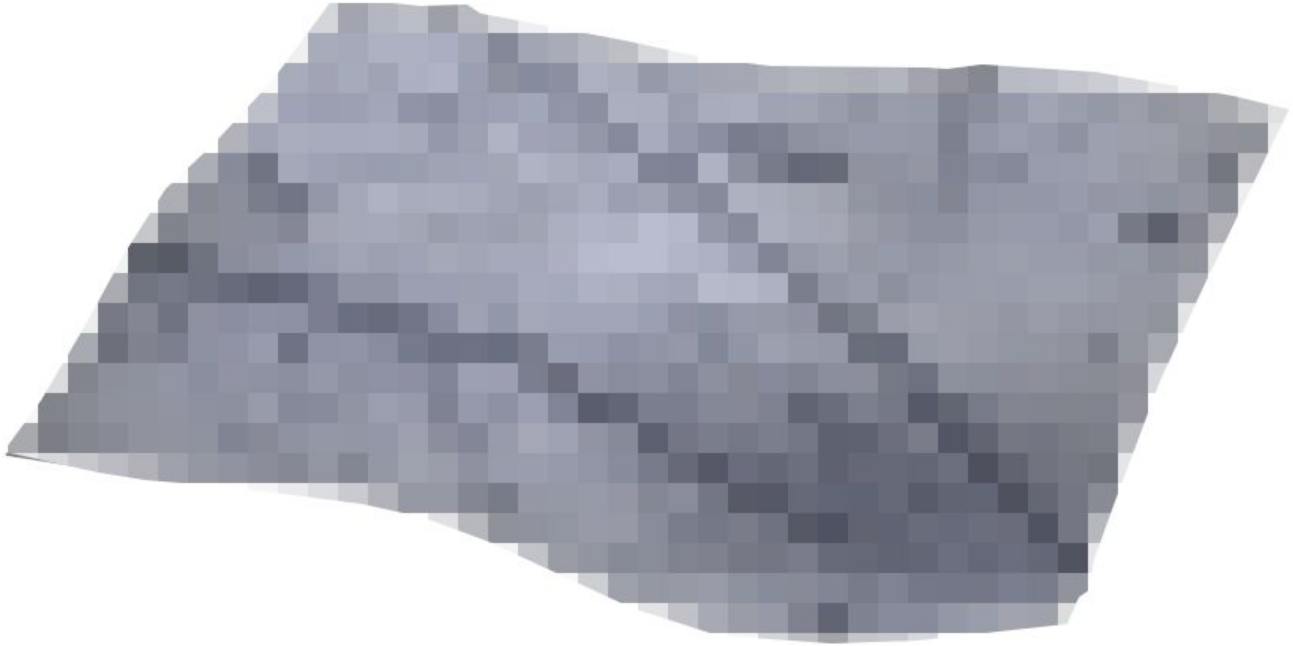

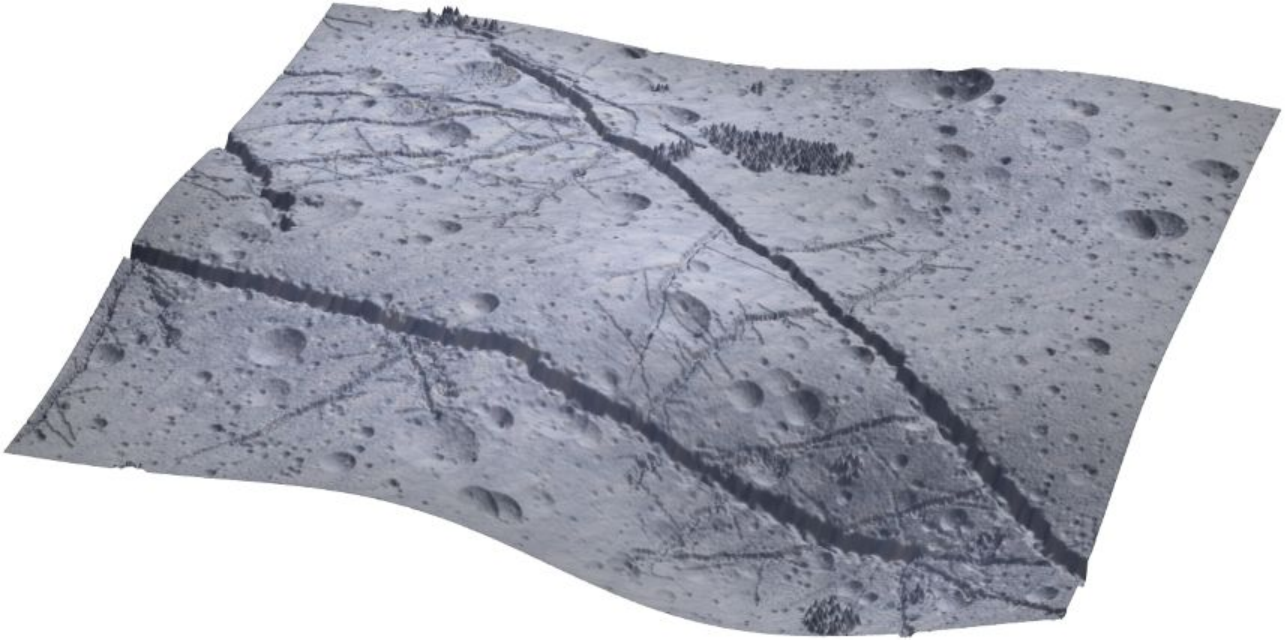

Risk Constraints Planetary Robots

- Planetary missions have a risk posture which curtails directions for exploration.
- Scientific value is **inversely proportional** to terrain safety.
- But we don’t know what the terrain is like until we get there!

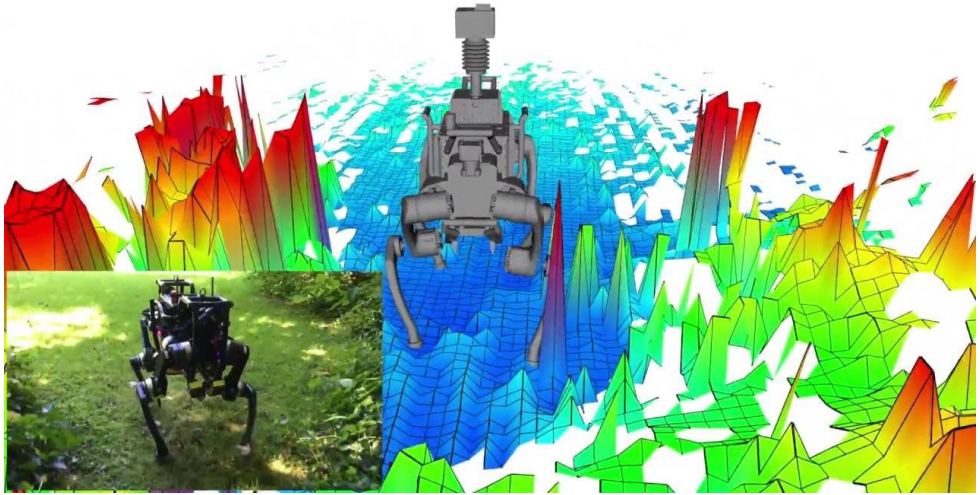

Image source: Robotic Systems Lab

Risk Constraints Planetary Robots

- Planetary missions have a risk posture which curtails directions fo
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Conflicting Priorities:
Killing the robot is **bad**! vs Learning is **good**!

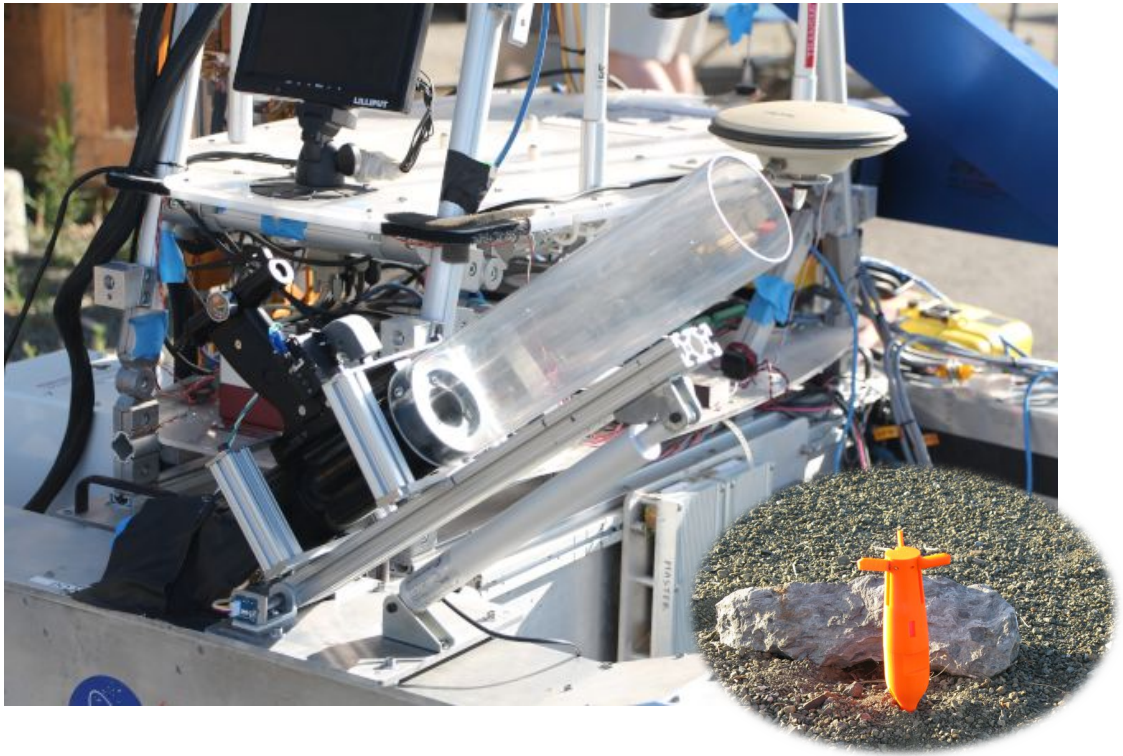
Image source: Robotic Systems Lab

Can We Sample Without Sending the Robot?

- Yes! Small, remotely deployed daughtercraft containing sensors
- *E.g.*, NASA Ames (Michael Dille and Uland Wong) has developed PHALANX, a deployable sensor system for mobile robots

M. Dille et al. PHALANX: Projectile Hordes for Advanced Long-term & Networked Exploration, IEEE Aerospace Conference (2020).

PHALANX - A Brief Overview



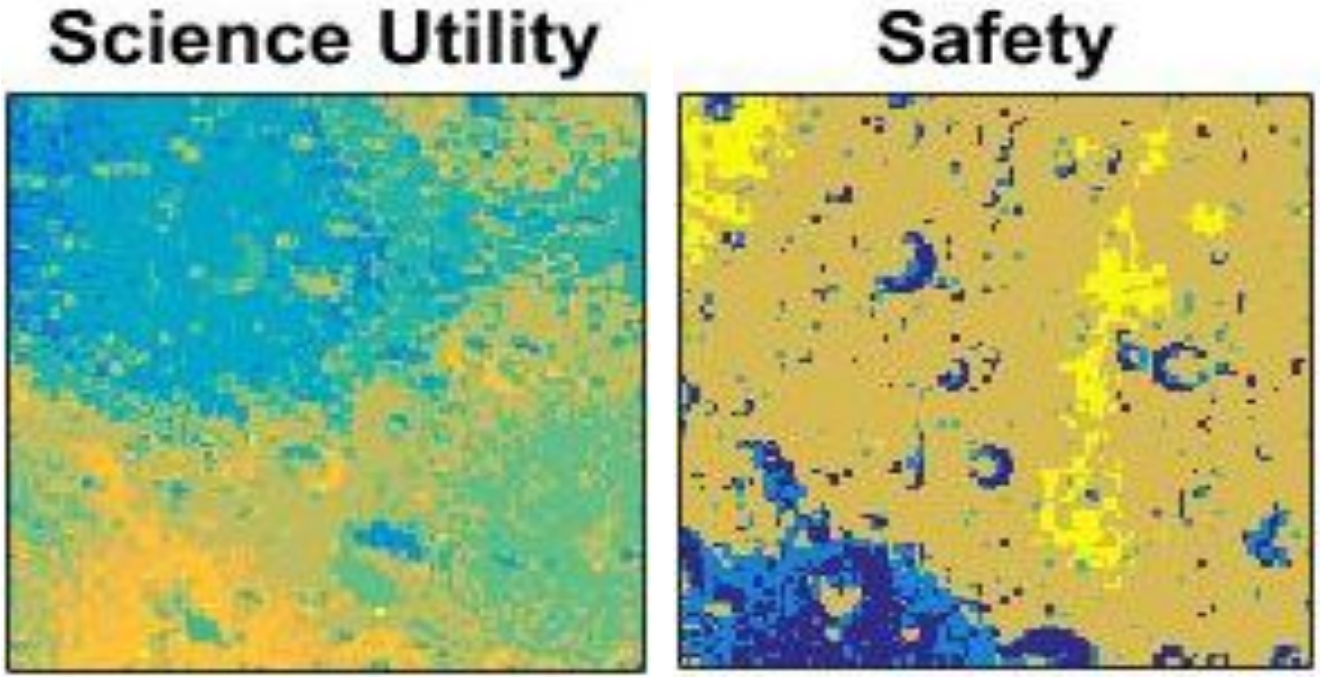
- Extends robot sensing reach
- Small sensor packages
  - < 250g, < 75mm diam
- Different sensor types
  - Heterogeneous, mission-specific tailoring
- Payload of 25-50 sensors
- Mortar delivery system
  - 10-100m deployment range

But….how do you choose?

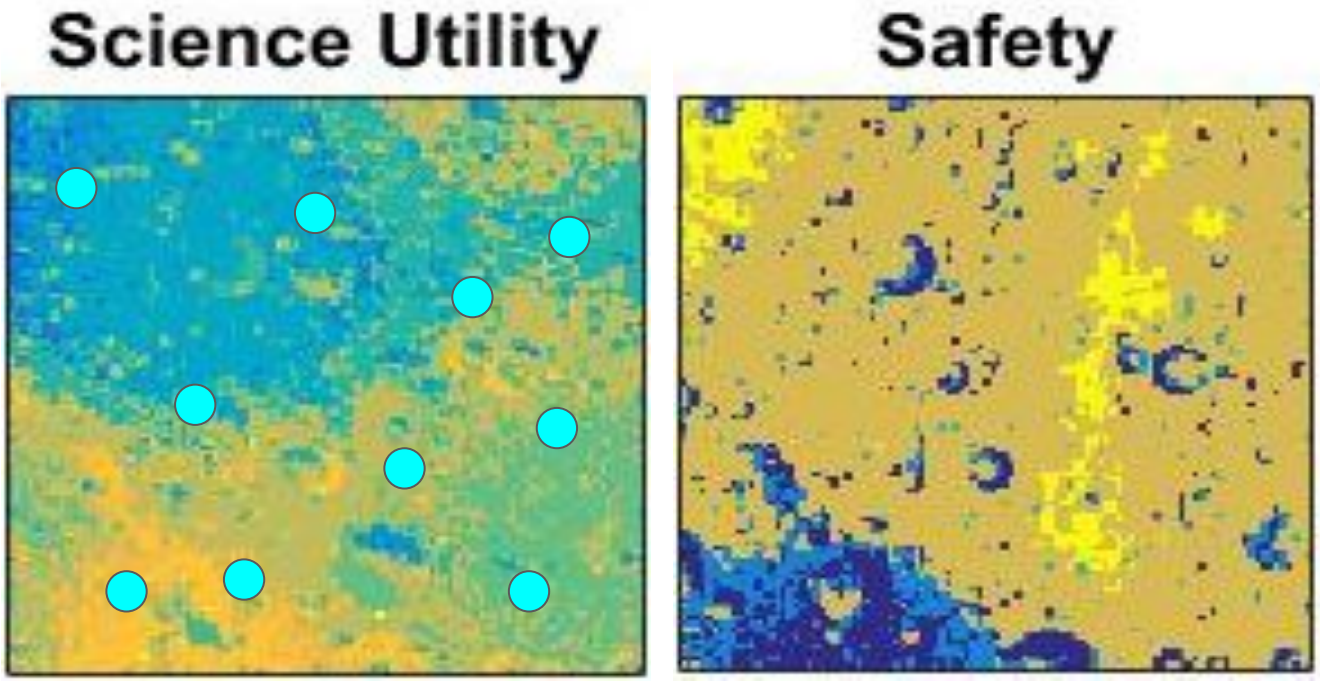
Need to play off the best deployment of sensors against your expectation of what the world looks like.

- Simulate risk and observations from precursor (e.g. pre-mission) data.
- React *in situ* as needed.

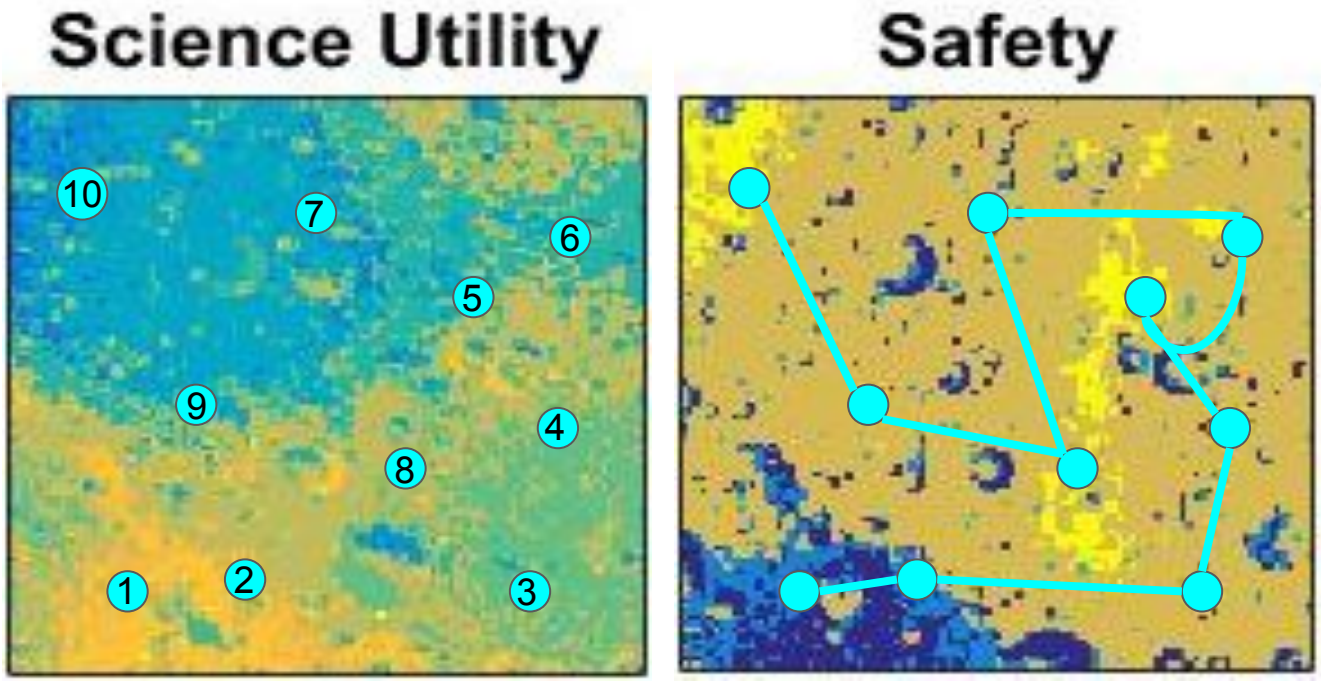
Concept of Operations - Collect Precursor Data



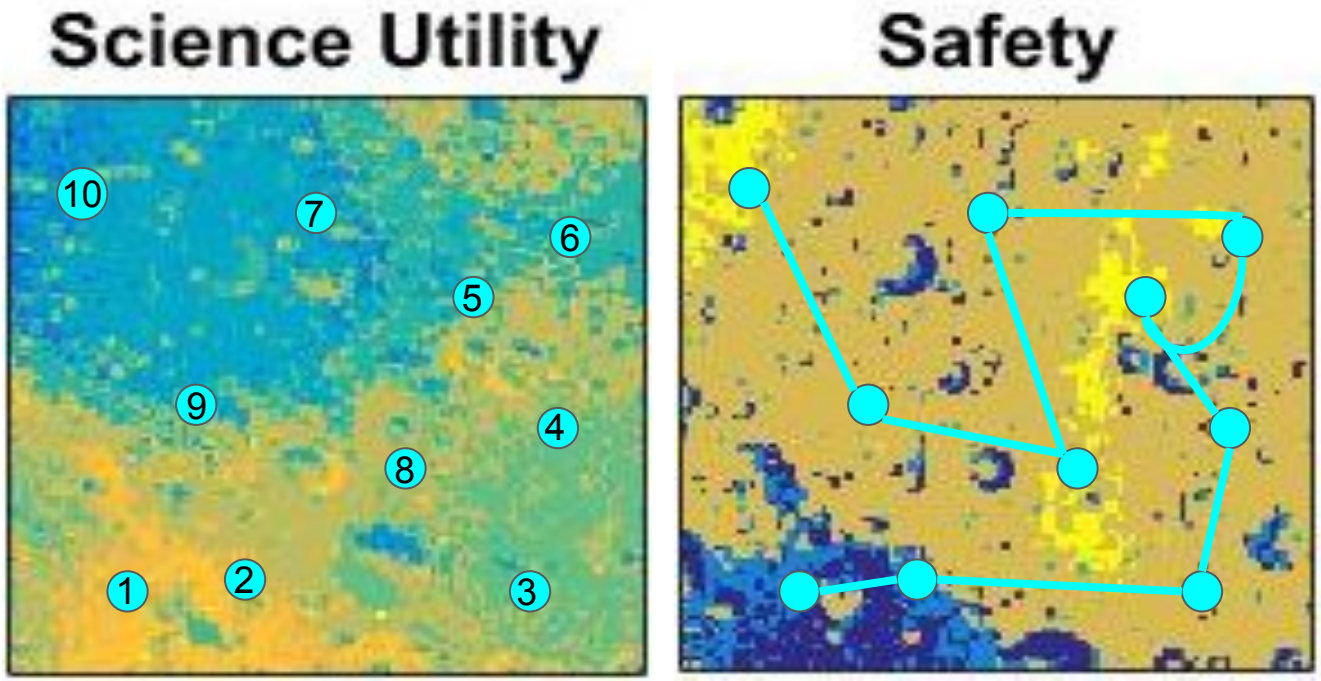
Concept of Operations - Identify Valuable Samples



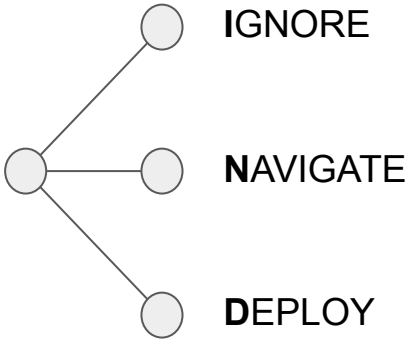
Concept of Operations - Plan a Tour



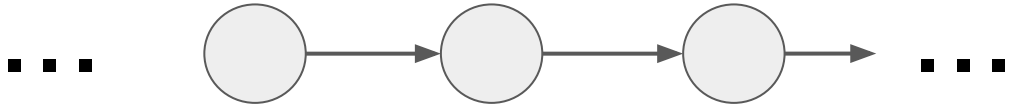
Concept of Operations - Plan a Tour



How do we make good decisions?

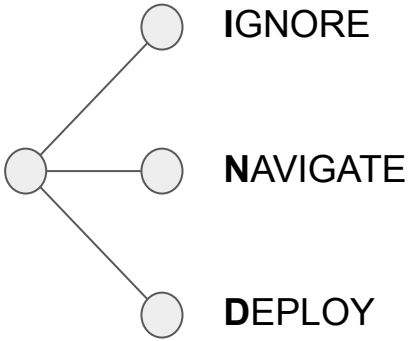


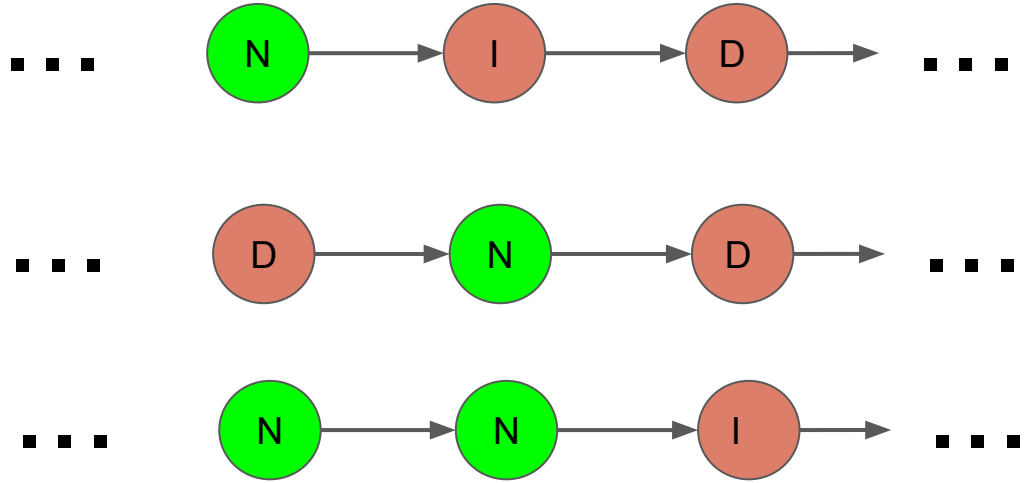
Make the best decision now



Assuming we behave optimally later

How do we make good decisions?



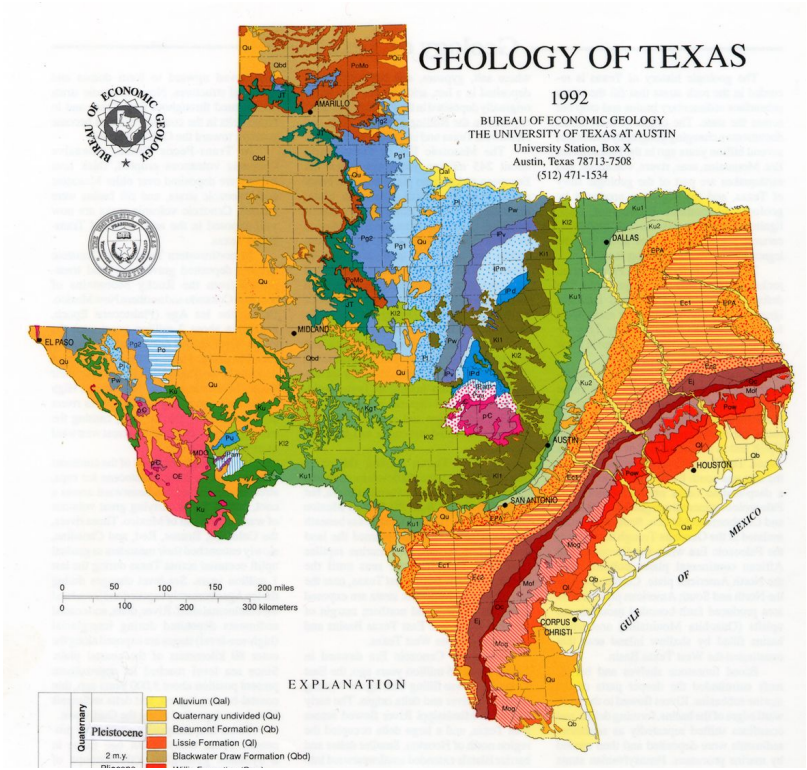


Make the best decision now

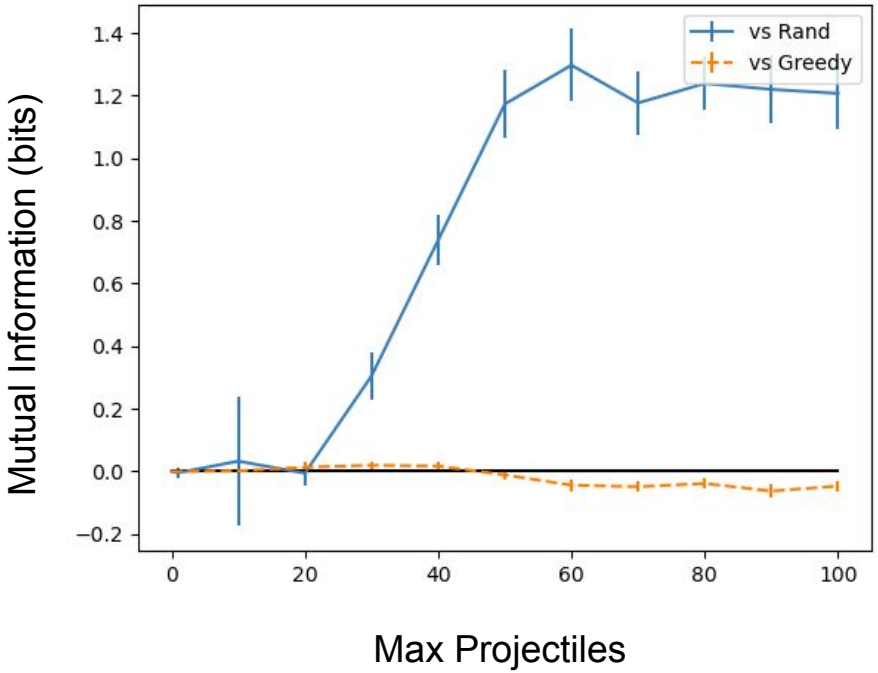
Given average return over future deployments with sampled future terrain safety.

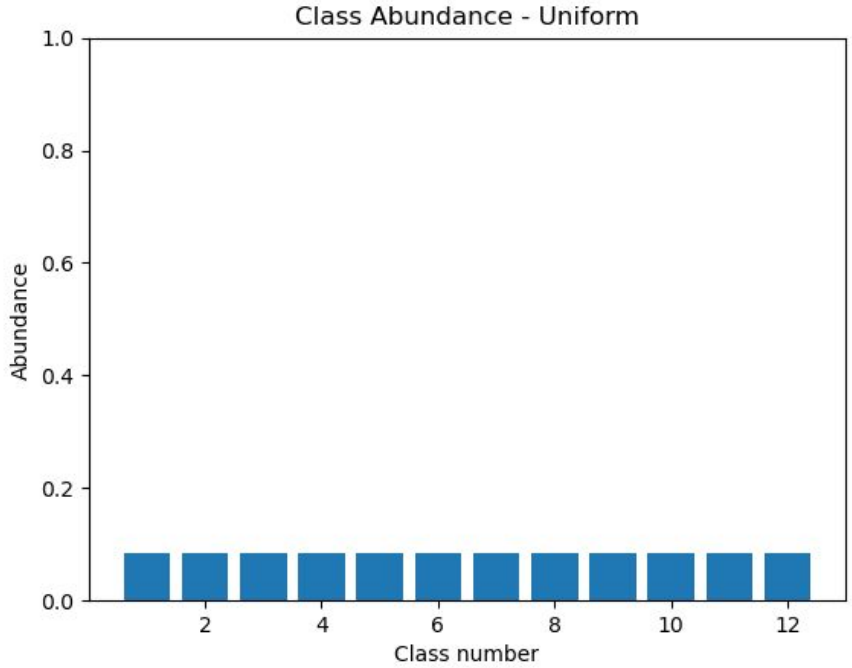
Simulation for Algorithm Comparison

- 100 Locations
- Probability of hazard ~ Uniform(0,1)
- 12 Classes of objects (science targets)
  - Modelling underlying distribution(s)
- Baselines:
  - **Random:** Sample unsafe locations on coin flip
  - **Greedy:** Sample unsafe locations as encountered

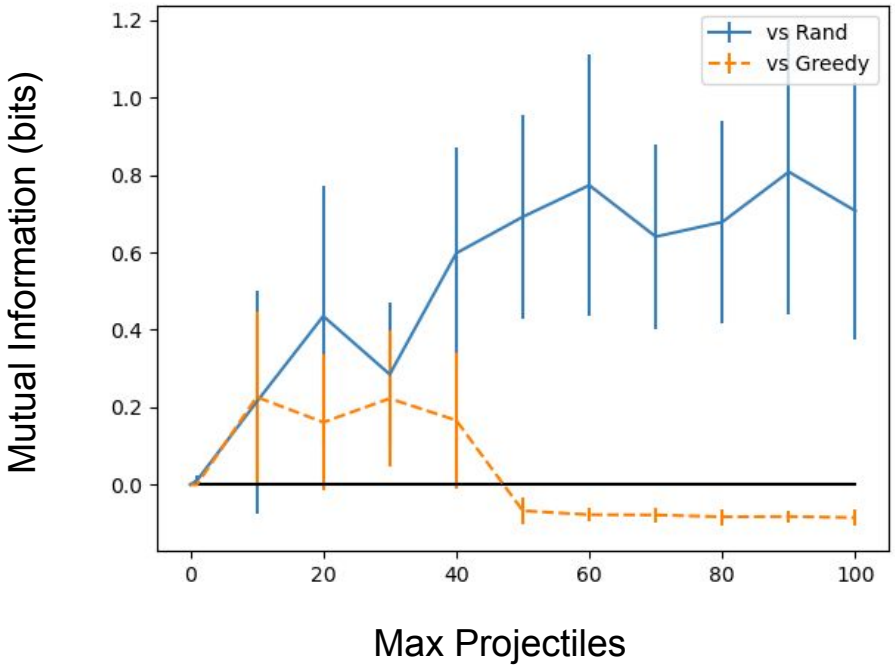


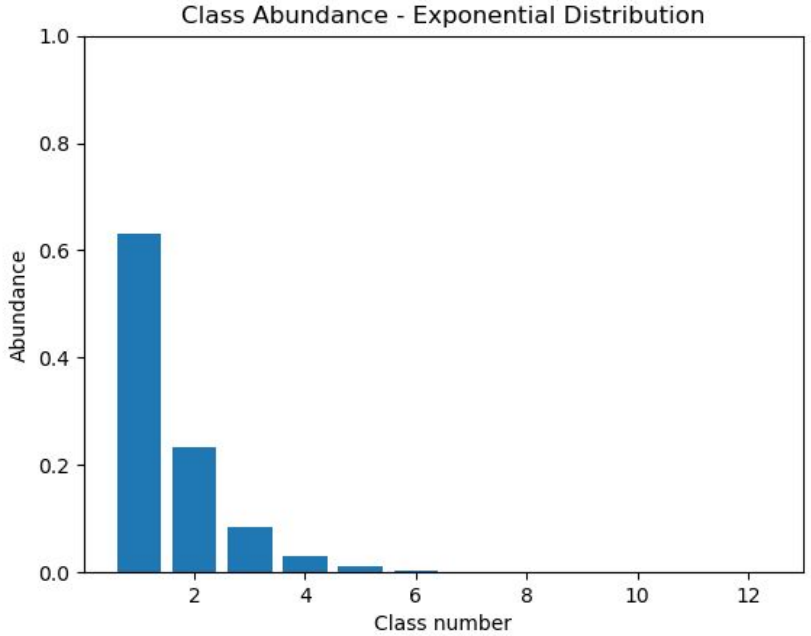
Performance - Uniform Abundance



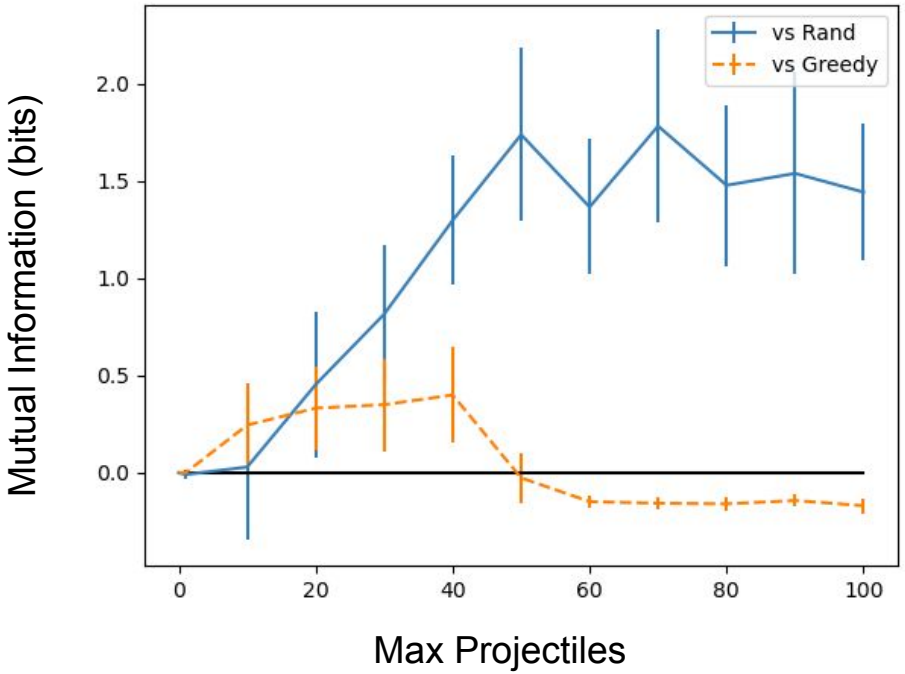


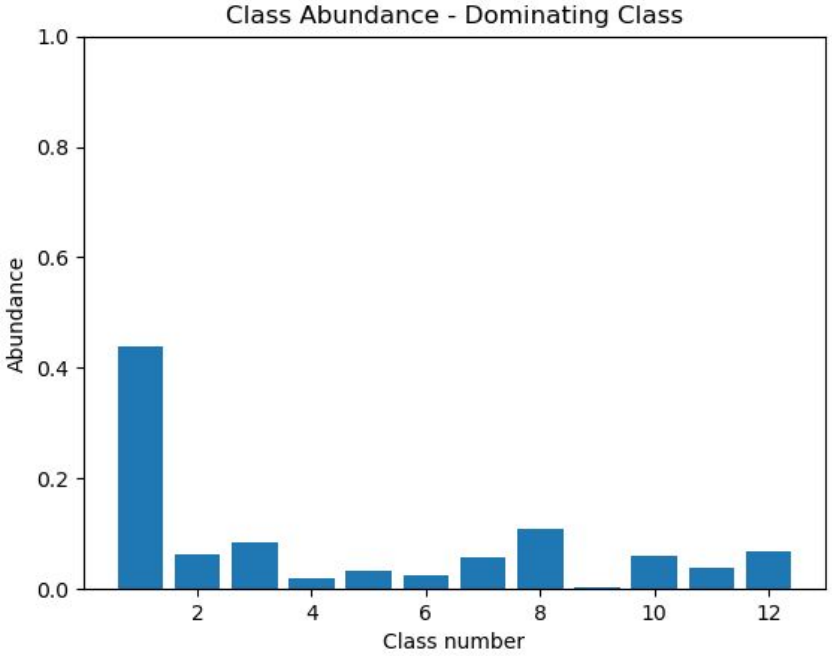
Performance - Exponential Abundance





Performance - Dominating Class





Conclusions

1. As good or better for tested scenarios
2. Useful formalism for decision-making/mission-planning
3. Room for improvement
    a. Future estimated value implementation is naive
    b. On-line updating of safety estimate

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